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Clickers in an introductory statistics course

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Abstract

This paper reports on a pilot study of the use of an student response system, commonly known as clickers, in an introductory statistics course. Early results show a small but significant increase in grades following the introduction of clickers. A Statistics Concept Inventory (SCI) was also used to assess students' understanding of the course concepts. The usefulness of the SCI was partially supported, as many questions were better answered by more able students.

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1. Introduction

Clicker technologies were first used in educational settings in the 1960s [1]. Before that they had been used by businesses to collect data in meetings, and by government to collect and display votes in parliamentary settings, for example. Much academic literature makes reference to television programs that also use audience response systems, such as "Who wants to be a Millionnaire?".
An array of different disciplines have tried clickers in classes, ranging from nursing [2] and biology [3] to environmental science [4] and finance [5].

2. Educational setting

Introduction to Statistics at the University of Canberra (UC) is a service unit that consisted of three hour lectures and one hour tutorial per week. Although no extraneous mathematics was introduced with the statistical concepts, the unit contained a significant amount of theory and formulae. There was some attempt to contextualize the learning however students often failed to acquire the Statistical language appropriate for application in their education and future professions. We recognized this as a key area for improvement and following a successful bid for institutional teaching and learning development funds, we set about revamping the way in which statistics was taught, in order to make the subject more successful for the students by utilizing some language learning strategies.

2. Project description

The project was concerned with redesigning the delivery of statistics to first year undergraduates and postgraduates with no prior Statistics study. In line with recommendations [6] we initially concentrated on what it was that we felt students needed to know and be able to do following the teaching sessions. The goals of the project were to:

- ensure that students were equipped with skills in interpreting data that would enhance their future performance in their chosen field of study;
- improve students' ability to use data to inform their practice in their chosen area of study, thus arriving at greater understanding of the underlying statistical principles;
- increase the amount of learner-centeredness in appreciating the role of statistics;
- develop online materials that allowed students flexible access, and more opportunities to interact with materials at their own pace.

This project concentrates on benefits that students perceive and display over one semester only. A future longitudinal study could address benefits over longer periods of time.

Initial implementation of the strategies above took place in 2008, and are described in [7].

As well as all the strategies described above, clickers were used on a weekly basis during semester. The questions were multiple choice questions, with generally just three choices, gathered from [8]. There is no anecdotal evidence that students realised the source of the questions. If they had, they would have been able to prepare for the clicker questions, but there are 10 multiple choice questions per chapter so a lot of extra effort for little direct reward.

TurningPoint software, which connects to Microsoft Powerpoint, was employed to run the clicker sessions. One question had to be removed from the analysis when it was discovered that due to a cut-and-paste error, the three multiple-choice options were identical! This did not stop students selecting a variety of responses, which caused much laughter in class when the mistake was discovered. For more very honest and personal experiences with clickers in class, see [9].

A practice clicker session was held in week 1, with students responding to questions such as "What is your gender?" and "Which degree are you enrolled in?" During the course of the semester, clickers were handed out at the start and collected at the end of each class that they were required. None were lost during the semester, and only one clicker stopped working during the semester. Class size was small (no more than 40 on any one day) so not a great deal of time was lost in this exercise. See [10] for a discussion of the handling of clickers in larger classes.

3. The clicker experience during the semester

The number of students who answered clicker questions varied from 10 to 24, with a mean of 19 and a standard deviation of 3.

An ANOVA was conducted to test whether question type (descriptive, graphical, probability, design and inference) has a significant effect on the mean percent correct. There was no significant difference ($F = 0.193$, $p = 0.939$, df = 4 and 20). This suggests that clickers can be used successfully across all parts of the introductory statistics curriculum.

We identify three main patterns of response across the 24 questions that had three alternative responses.

1. Clear majority, where the percentage choosing one response (not necessarily the right one, but it was in) is more than the sum of the percentages choosing the other two responses. Twenty of the 24 questions were answered in this way. Recall that these questions were typically administered at the end of a lecture on a given topic, and so it is not surprising that students knew the answer. Only once did the majority get it wrong: is a question on the stems of stem-and-leaf plots, the majority chose 00, 10, 20, …, 90 when they were supposed to choose 0, 1, 2, …, 9. It is hardly surprising that a majority of students were led astray in their selection of a response when two of them are so similar and almost come down to a typesetting issue! We also note that the questions were taken directly from [8]. The questions are "straightforward questions about basic facts from the chapter" and students are told that they "should expect all of your answers to be correct".
2. Split across two, either with percentages such as 50/45/5. Two questions went this way. One was a question about the scale invariance of the correlation, and the other involved students recognising that a lengthy description was of a completely randomised experiment.
3. Split across three e.g. 38/23/38. Three questions went this way. One involved calculating a five-number summary, one involved identifying a null hypothesis from a lengthy description and the other involved identifying an experiment that was not matched pairs from three lengthy descriptions.

From the very small number of questions that led to a split, it appears that problems can arise when a little bit of calculation is required, or when there is a fair amount of reading (70 - 80 words). Students also complained when questions were presented that required a page of output, followed by questions on the next slides. Our advice is to provide students with a handout with attached graphs and output to assist with timely comprehension of the background to the questions.

The responses to clicker questions cannot be tied to individual students, although some systems do allow for this to be done. Anonymity of response is a selling point to some students, while other lecturers use the clickers as part of formal assessment and therefore need to be able to record individual students' responses [11].

4. Results at the end

Student learning outcomes were measured through four in-class tests, a final exam, and a Statistics Concept Inventory [12].

Table 1 shows that while the means of the control group (CG) and the experimental group (EG) for test 1 and 2 are not significantly different, for test 3 the differences in means are significant at the 5% level. For test 4, the means are significantly different but EG scores lower than CG. This may be due to the fact that there were two significant errors in the EG paper, and furthermore different topics were tested in the two groups: two-sample hypothesis tests and regression in EG and regression and analysis of variance in CG.

Table 1. Results of assessment items for CG and EG.

	group	
	language (2008, CG)	clickers (2010, EG)
assessment	mean (s.d.) n = 22	mean (s.d.) n = 28
Test 1 (30)	21.8 (4.7)	22.1 (5.0)
Test 2 (30)	20.5 (4.7)	20.1 (5.8)
Test 3 (30)	19.1 (6.7)	20.0 (4.4)
Test 4 (30)	20.5 (5.7)	21.0 (5.7)
SCI (22)	NA	14.5 (4.3) (n = 22)
Exam (100)	61.5 (21.5)	65.2 (15.2)

Table 2 shows the distribution of grades in the final examination for 2008 and 2010, after eliminating students who passed the unit on in-term assessment and chose not to attempt to improve their grade by sitting the examination. A χ^2 test shows that there are no significant differences ($X^2 = 4.05$, $p = 0.3944$, df = 4) between the grade distributions for the two groups. Data on UAIs and GPAs for these students was too sparse to be able to confirm the effect in 2008 where credit-level students appeared to be achieving at a Pass or a Distinction level in this unit.

Table 2. Grade distribution for CG and EG.

grade	group	
	language (2008) n = 20	Clickers (2010) n = 28
Fail	5.0	10.7
Pass	40.0	35.7
Credit	5.0	21.4
Distinction	35.0	17.8
High Distinction	15.0	14.3
Total	100.0	99.9

Tables 1 and 2 together can be interpreted as general evidence that the new teaching model does promote learning in students, particularly in obtaining a Pass grade at a minimum.

Other research [13] found a correlation of 0.57 between clicker scores and final exam marks. His sample size is reported to be 24, although the accompanying scatter plot appears to have about 40 observations. We are not able to comment on the correlation in this data, as it is not possible to link clicker scores and exam marks. It is however possible to link attitudes towards clickers and exam marks, as discussed in the next section.

5. Affective aspects of clickers

Six questions asked on a five-point Likert scale, scored from 1 = strongly disagree to 5 = strongly agree:

- I used the clickers in class
- The clicker questions helped my understanding during class.
- The clicker questions helped my revision.
- I would recommend the use of clickers to other statistics classes in particular.
- I would recommend the use of clickers to other university classes in general.
- Please add any comments.

If the clicker scores are summed, the maximum possible score is 25. The 22 scores obtained were approximately Normally distributed, with a mean of 19.95 and a standard deviation of 2.87. This suggests that the recorded reaction to clickers was positive, which may however mean that only those who had enjoyed using the clickers may have bothered to respond.

So the students who responded to the clicker survey were uniformly positive about it, but did those students actually perform better than those who did? Independent-samples t tests comparing test and exam marks between the 22 students who did respond to the clicker survey and the 11 students who did not show no significant difference in mean scores (p = 0.286, 0.226, 0.624, 0.831 and 0.290 for tests 1 – 4 and the exam respectively.) So while they did not show a significant difference in their mean test results, we can take this to indicate that a student's attitude to the clickers may not influence their exam result, but their usage of them still might. Only one student who responded to the clicker survey had used them less than "three or four times".

Another way to look at whether good students use clickers is to study the relationship between the qualitative aspects of clicker use and exam marks. The relationship is weakly positive and not statistically significant ($r = 0.337$, $p = 0.202$, $n = 16$).

Students were also invited to comment on the clickers. Eleven students took up the invitation and their comments were uniformly positive. Some reinforced the positive aspects of clickers e.g. "It can help the students review the key points and find the weakness quickly"; "Clickers give us opportunity to learn from our mistakes".

Some recommended greater use e.g. "I think we might have attempted more clickers, if we had more time during our semester."

Some recommended variations in use. "I believe the clickers are excellent for on the spot feedback [to] help direct [the] lecture. The part that is hard to tell is when further explanation is given, how to tell that it is understood? Should there be a second similar question given after the further explanation from the first, this could see if the results increase to show that students

understand!" It is worth reiterating that the questions selected were revision questions from [8] and the author himself emphasises that by the end of a chapter, students should be able to answer all these questions correctly.
"I reckon clickers are a very good tool to understanding more in lectures, however you lose out when you cannot attend lectures and listen to them online." Lectures were recorded using the audio-only system Audacity. A system such as Echo360. which captures both voice and Powerpoint, should improve the capacity of students listening asynchronously to benefit from the clicker questions

Finally, there were several general comments such as "Thanks for making statistics easy by adding activities like clickers".

6. Conclusions

A distinction should be made between retention of knowledge from the first course to subsequent ones, and capstone courses. A capstone Statistics course, using a book such as [14] or [15], aims to integrate knowledge from many previous courses, not just one. Typically such a course is case study-based, involving a mixture of basic techniques such as exploratory data analysis with advanced techniques such as generalised linear and multilevel models.
We have described above a project that brought together experts from language teaching and statistics to produce a new teaching/learning model for beginning students. We evaluated this new approach and demonstrated that we have made a statistically significant difference to students' performance in tests and exams, improved their understanding of some key concepts and their ability to view statistics in relation to their professional practice. It is this multi-sensory approach to delivery that we would recommend to others. A caveat is that the groups of students involved in this project were fairly small (around n = 25). Consequently, we need to act with caution if we are to apply these new teaching strategies to a larger group of students, say, of size 200. Admittedly, the size of the student cohort might make group work more difficult but with attention paid to management issues related to a larger size group, it is still possible to implement such group work. For some group work management ideas, see [16].

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